Research Article

Waste Rice for Waterfowl in the Mississippi Alluvial Valley

JOSHUA D. STAFFORD,[1,2] *Department of Wildlife and Fisheries, Mississippi State University, Mississippi State, MS 39762, USA*
RICHARD M. KAMINSKI, *Department of Wildlife and Fisheries, Mississippi State University, Mississippi State, MS 39762, USA*
KENNETH J. REINECKE, *U.S. Geological Survey, Patuxent Wildlife Research Center, Vicksburg, MS 39180, USA*
SCOTT W. MANLEY, *Ducks Unlimited, Inc., Tri-State Field Station, Cape Girardeau, MO 63701, USA*

Abstract

Flooded rice fields are important foraging habitats for waterfowl in the lower Mississippi Alluvial Valley (MAV). Waste rice previously was abundant in late autumn (140–492 kg/ha), but early planting and harvest dates in recent years may have increased losses of waste rice during autumn before waterfowl arrive. Research in Mississippi rice fields revealed waste-rice abundance decreased 79–99% during autumns 1995–1996 (Manley et al. 2004). To determine if this trend existed throughout the MAV, we used multistage sampling (MSS) to estimate waste-rice abundance during September–December 2000–2002. Averaged over years, mean abundance of waste rice decreased 71% between harvest ($\bar{x} = 271.0$ kg/ha, CV = 13% n = 3 years) and late autumn ($\bar{x} = 78.4$ kg/ha, CV = 15% n = 3). Among 15 models formulated to explain variation in rice abundance among fields and across years, the best model indicated abundance of waste rice in late autumn differed between harvester types (i.e., conventional > stripper header) and was positively related to initial waste-rice abundance after harvest. Because abundance of waste rice in late autumn was less than previous estimates in all 3 years, we concluded that waterfowl conservationists have overestimated carrying capacity of rice fields for wintering waterfowl by 52–83% and recommend 325 duck-use days/ha (DUDs) as a revised estimate. We suggest monitoring advances in rice harvest dates to determine when new surveys are warranted and recommend increased management of moist-soil wetlands to compensate for decreased rice abundance. (JOURNAL OF WILDLIFE MANAGEMENT 70(1):61–69; 2006)

Key words

carrying capacity, conservation planning, estimation, food resources, foraging, Mississippi Alluvial Valley, rice, sampling, waterfowl.

Historically, the Mississippi Alluvial Valley (MAV) was a bottomland–hardwood ecosystem and flooded frequently during winter and spring (Reinecke et al. 1989). Development during the 19th and 20th centuries converted these forested wetlands in the MAV to a predominantly agricultural landscape. By 1978, 79% of the original forested area in the MAV had been cleared (Forsythe and Gard 1980, Forsythe 1985), and flood control projects had greatly altered natural hydrology (Galloway 1980, Reinecke et al. 1988). Despite these changes, the MAV has remained a critical region for North American waterfowl and other wildlife (Reinecke et al. 1989).

In 1986, the United States and Canadian governments endorsed the North American Waterfowl Management Plan (NAWMP) as a strategy for continental waterfowl and wetlands conservation (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986). The NAWMP encouraged formation of regional habitat conservation and management initiatives to restore North American waterfowl populations to mid-1970s levels. The Lower Mississippi Valley Joint Venture (LMVJV) was organized by federal, state, and nongovernmental partners to conserve waterfowl populations in the MAV and established an objective of providing adequate wetland habitat on public and private lands to support waterfowl and other wetland wildlife (LMVJV Management Board 1990). Pursuant to this objective, the LMVJV implementation plan recommended winter flooding of harvested croplands to provide foraging habitat for waterfowl.

Rice is a major crop in the MAV, and its grain provides important food for migrating and wintering waterfowl (Reinecke et al. 1989). Indeed, the extent of ricelands is great in the MAV, and harvested area averaged 611,680 ha in Arkansas, 99,085 ha in Mississippi, 32,923 ha in Louisiana, and 43,126 ha in Missouri during 1999–2003, collectively representing 63% of the total rice harvested in the United States (National Agriculture Statistics Service 1999–2003). Regarding potential food availability for waterfowl, waste rice (i.e., grain not collected by harvesters) continues to be abundant in MAV fields after harvest (140–492 kg/ha; Reinecke et al. 1989, Huitink and Siebenmorgen 1996, Manley et al. 2004). Rice seeds are considered quality waterfowl forage because they were found to be more nutritious than corn or soybean in experiments with captive waterfowl (Joyner et al. 1987, Loesch and Kaminski 1989) and because rice seeds resist decomposition (Shearer et al. 1969, Nelms and Twedt 1996). Furthermore, rice is grown in paddies that facilitate flooding after harvest, thereby conveniently creating winter wetlands for migrating and wintering waterfowl. Finally, winter flooding of rice fields is agronomically and environmentally beneficial, having been shown to increase soil and nutrient retention, promote decomposition of straw, and retard growth of winter weeds (Bird et al. 2000, Manley et al., in press).

Although waste rice provides important waterfowl food in the MAV (Loesch and Kaminski 1989, Reinecke et al. 1989), its abundance in late autumn may have decreased recently. Reinecke et al. (1989) reported mean waste-rice abundance in Arkansas fields was 223 kg/ha in late autumn 1983 and 140 kg/ha in 1984. Introduction of new rice varieties in the early 1980s enabled earlier planting and harvesting (Anders, in press). When harvest occurs in late summer (i.e., Aug–Sep), waste rice is exposed for greater time to decomposition, germination, and granivory before arrival of waterfowl. Accordingly, Manley et al. (2004) reported a 79% decline in waste rice from 492 kg/ha in August–September 1995–1996 to <81 kg/ha in early December in 4 Mississippi counties. If

[1] *E-mail: stafford@inhs.uiuc.edu*
[2] *Present address: Illinois Natural History Survey, Bellrose Waterfowl Research Laboratory, Forbes Biological Station, Havana, IL 62644, USA*

waste-rice abundance throughout the MAV in late autumn was less than previously believed, current LMVJV conservation plans may be overestimating the foraging carrying capacity of rice fields for waterfowl.

Because waste-rice abundance was a key uncertainty for the LMVJV and no data existed at temporal and spatial scales appropriate for conservation planning, we sampled rice fields throughout the MAV during autumns 2000–2002 to assess their value as foraging habitats for wintering waterfowl. Our objectives were to 1) estimate waste-rice abundance during 4 time periods each of 3 years to evaluate dynamics of waste rice in autumn and potential availability to waterfowl in early winter; 2) determine if estimates of waste rice were biased by incomplete recovery of seeds from soil samples; 3) model variation in mean rice abundance among fields in late autumn as a function of weather, latitude, harvest methods, and postharvest tillage; and 4) make management recommendations consistent with our results.

Study Area

Our study area was the MAV, a 10-million ha floodplain extending from southeast Missouri along the Mississippi River to the Gulf Coast of Louisiana. Reinecke et al. (1989) described the MAV and its wintering waterfowl populations and habitats. Our study sites were rice fields distributed throughout the MAV except in areas where little rice was grown, such as Crowley's Ridge in northeast Arkansas and southeast Missouri and Macon Ridge in southeast Arkansas and northeast Louisiana. Uihlein (2000) surveyed the extent of waterfowl habitat provided by rice fields in the MAV and estimated 80,830 ha of harvested rice fields were flooded in winters 1992–1993 through 1994–1995.

Methods

Sampling Design and Implementation

We used multistage sampling (MSS) to estimate rice-seed abundance in harvested rice fields in the MAV with a goal of estimating the overall mean with a CV $\leq$ 15% (Seber 1982:64, Conroy et al. 1988). This procedure was designed to consider the inherent clustering of our sample units (e.g., fields within farms; Cochran 1977) and facilitated construction of a practical sampling frame (i.e., landowners who managed rice fields for waterfowl). Our sample design treated rice producers as primary sample units, rice fields farmed by each producer as secondary units, and core samples extracted from fields as tertiary units.

The target population in our study was all winter-flooded rice fields in the MAV. However, a list of all fields was not available, and we used a database of private landowners who enrolled rice fields in conservation programs with Ducks Unlimited (DU), Inc. (Southern Regional Office, Ridgeland, Mississippi, USA) as our sampled population. Based on discussions with rice agriculturists, we assumed the rice fields of landowners in the database were representative of rice fields in the MAV and received agricultural practices similar to those outside conservation programs. We believed this assumption was reasonable because the primary goal of rice landowners in our sample was to produce rice for grain markets and subsequently manage these fields outside the production season for wintering waterfowl and other benefits (Manley et al. 2004, Manley et al., in press). Recent estimates indicated that fields in DU programs comprised 22% in both 2001 and 2003 of the total area of winter-flooded agricultural lands in the MAV (176,304 ha [2001] and 178,400 ha [2003]; C. A. Manlove, Ducks Unlimited, Inc., unpublished data).

Annually, we obtained an updated database, queried it to identify landowners who farmed rice, and randomly selected a predetermined number. We used means and variances from Manley et al. (2004) to estimate sample size for year 2000 and cumulative data from the preceding years of our study to estimate sample size for 2001 and 2002 (Stafford 2004). We used PROC SURVEYSELECT in SAS v8.2 (SAS Institute 1999) to select landowners randomly and with replacement, and to ensure geographic representation, we stratified by state (Arkansas, Louisiana, Mississippi, and Missouri) and allocated samples to states proportional to area of harvested riceland (Lohr 1999:95). When we visited landowners to obtain permission to sample, we randomly selected fields (secondary units) from those available on each farm. In 2000, we sampled 1 or 2 fields per landowner, whereas in 2001 and 2002 we sampled 2 fields per landowner. We randomly extracted 10 core samples (10 cm diam and depth; 785.4 cm^3) from each field using standard techniques (Manley et al. 2004). We replicated the survey each year during 1) 21 September to 11 October; 2) 24–28 October; 3) 9–15 November; and 4) 27 November to 7 December 2000–2002. We refer to sampling period 4 as late autumn with respect to potential availability of waste rice for waterfowl.

Laboratory Procedures

We washed samples through sieves (i.e., mesh sizes 4 [4.75 mm], 10 [2.0 mm], and 18 [1.0 mm]) and removed rice seeds containing whole or partially intact (i.e., $\geq$50% of seed remained) endosperm. We considered germinated seeds to be potential waterfowl food if the primary root or shoot was less than or equal to the length of the seed and the endosperm was firm. We dried seed samples to a constant mass ($\pm$ 0.5 mg) at 87°C before weighing (Manley et al. 2004).

Statistical Analyses

Estimation of waste-rice abundance.—We used PROC SURVEYMEANS in SAS v8.2 to estimate mean waste-rice abundance (SAS Institute 1999, Stafford et al. 2003). This procedure analyzed data collected under MSS by incorporating appropriate weights and selection probabilities based on the 3 stages of sampling within strata. The probability of selecting a landowner was n_i/N_i, where n_i and N_i were the numbers of landowners selected and enrolled each year in stratum (state) i. Similarly, the probability of selecting a field was m_j/M_j, where m_j was the number of fields (1 or 2) selected among M_j fields enrolled by landowner j. Finally, the probability of selecting a soil core within a field was $10/(K_{ij}/8.107 \times 10^{-7})$, where the number of cores collected in each field was 10, and the potential number of cores was the area (K_{ij}; ha) of rice field j within landowner i divided by the area of a core sample (8.107×10^{-7} ha). The inverse of the product of the 3 selection probabilities (i.e., landowner, field, and core) was the weight used in analyses. SURVEYMEANS used Taylor series linearization (i.e., the Delta method; Seber 1982:7) to estimate variances of means for MSS (SAS Institute 1999:3200).

We calculated an overall estimate of mean rice abundance as an unweighted mean of annual means ($\bar{x}$). We estimated variance of the overall mean, var($\bar{\bar{x}}$), as:

$$\mathrm{var}(\bar{\bar{x}}) = \frac{\sum_{i=1}^{n} \mathrm{var}(\bar{x}_i)}{n^2}$$

where var($\bar{x}$) was the estimated variance associated with mean rice abundance in year i, and $n=3$ years. This estimate represented the average sampling variance during our study period but did not account for process variance (i.e., interannual variation; Burnham et al. 1987) because we desired an overall estimate of variance in averaged rice abundance that was representative of the years of our study (Franklin et al. 2002:268–269).

We used PROC SURVEYREG to quantify variation in rice abundance among and within years because this program accounts for stratification and clustering in complex sample designs (SAS Institute 1999). We fit a model with additive effects of the class variables, year and sampling period, and used the CONTRAST option in SURVEYREG to test for differences in rice abundance among years for sampling periods of greatest interest (i.e., postharvest and late autumn). Because sampling events were temporally consistent among years and separated by approximately 2 weeks, we also fit a model, with year as a class variable, and sampling period as a continuous variable, to estimate the rate of change in rice abundance among sample periods.

Estimation of seed-recovery bias.—Because rice abundance would be underestimated if seed recovery from core samples was incomplete, we conducted experiments with samples containing known numbers of rice seeds to estimate a bias correction. During autumns 2000–2002, one of the authors (K. J. Reinecke) prepared test samples containing known numbers of seeds. Test samples consisted of soil, with no history of rice production, and representative amounts of plant detritus. Assuming rice seeds weighed 0.0158 g dry mass (Delnicki and Reinecke 1986) and test samples were the same size as field samples (10 cm in diam and depth), numbers of seeds added to samples represented the range of values expected to occur in field surveys (i.e., 3–25 seeds/sample, 60–500 kg/ha). We coded samples to ensure a blind experiment, and technicians processed test samples identically to those collected in field surveys. We processed 10 test samples during autumn 2000, including 2 replicates at each of 5 levels of seed abundance (5, 10, 15, 20, and 25 seeds/sample). In autumns 2001–2002, we processed 24 test samples, including 4 replicates at each of 6 levels of rice abundance (3, 5, 10, 15, 20, and 25 seeds/sample).

We used the ratio between numbers of seeds added and recovered as the dependent variable in all analyses because it represented a potential correction factor for incomplete seed recovery (i.e., bias). Because of a missing year–treatment combination (i.e., no samples with 3 seeds in 2000), we could not use a factorial analysis to determine if recovery ratio varied among years, treatment levels, or their interaction (Milliken and Johnson 1992:173–177). Instead, we created a variable representing combinations of treatments and years ($n = 16$ combinations) and used 1-way analysis of variance (ANOVA) in PROC GLM (SAS Institute 1999) to determine if recovery ratio varied by year–treatment combinations (Milliken and Johnson 1992:177). Additionally, we deleted data from 2 test samples (3.4% $n = 58$) because diagnostic analyses indicated these were outliers (i.e., Studentized residuals >3 and Cook's D values $>4/n$; Freund and Littell 1991:64–70).

Data from field surveys and the seed recovery experiment were independent; therefore, we adjusted survey estimates for seed recovery bias following Mood et al. (1974:180):

$$\hat{\bar{x}}_{adj} = \hat{R} \times \hat{\bar{x}}_{unadj},$$

where $\hat{\bar{x}}_{adj}$ represented mean rice abundance adjusted for seed recovery bias, $\hat{\bar{x}}_{unadj}$ mean rice abundance not adjusted for bias, and $\hat{R}$ the ratio of the known number of seeds in samples to the number recovered. Finally, we estimated variances of bias-corrected estimates (Mood et al. 1974:180) as:

$$\mathrm{var}(\hat{R} \times \hat{\bar{x}}_{unadj}) = \left[\hat{\bar{x}}^2_{unadj} \times \mathrm{var}(\hat{R})\right] + \left[\hat{R}^2 \times \mathrm{var}(\hat{\bar{x}}_{unadj})\right] + \left[\mathrm{var}(\hat{R}) \times \mathrm{var}(\hat{\bar{x}}_{unadj})\right].$$

Gross and ecological waste-rice abundance.—We presented waste-rice estimates as gross and ecological abundances. Gross abundance was mean dry mass of all rice seed, whereas ecological abundance was gross abundance minus a threshold abundance possibly not accessible by waterfowl (i.e., giving-up density; Stephens and Krebs 1986). Because past research suggested that dabbing ducks may not exploit waste rice when density was <50 kg/ha (Reinecke et al. 1989, Rutka 2004), we calculated ecological abundance as gross abundance minus 50 kg/ha.

Domain analysis.—Two rice harvest methods were common in the MAV (i.e., conventional and stripper-header combines). Conventional combines cut rice stalks, thresh rice from chaff, and discharge straw behind the machine. Combines equipped with stripper headers separate rice seeds from seed heads, leaving rice plants essentially intact but without seeds. To estimate waste-rice abundance for fields harvested by these 2 methods, we used the DOMAIN option in PROC SURVEYMEANS, which treated each harvest type as a subpopulation or survey domain (Cochran 1977:34–35, SAS Institute 1999). We compared annual and overall waste-rice abundance between harvest methods within sampling periods using z-tests. We used the Bonferroni method to maintain an experiment wise error rate of $\alpha = 0.05$ ($\alpha_{corrected} = 0.013$; Sauer and Williams 1989).

Modeling waste-rice abundance.—We used an information-theoretic approach to identify factors potentially influencing variation in rice abundance among fields in late autumn relative to spatial, environmental, and land management variables (Anderson et al. 2000). Specifically, we developed 15 candidate models including selected combinations of 6 independent variables. We expected rice abundance to increase with latitude (LAT) because shorter growing seasons decrease time available for seed germination and decomposition following harvest. We expected rice abundance to be negatively related to ambient temperature (TEMP) and cumulative precipitation during fall (PRECIP) because rice seed germinates when soil temperatures exceed 10°C (Yoshida 1981, Miller and Street 2000), and moisture promotes germination and decomposition. Based on

Table 1. Bias-corrected estimates, standard errors (SE), and coefficients of variation (CV) for mean waste-rice abundance (kg/ha, dry mass) in harvested fields managed for waterfowl in the Mississippi Alluvial Valley, 2000–2002. Estimates are from a multistage sample in which landowners were primary sample units, fields within landowners were secondary units, and soil cores within fields were tertiary units.

Year	Sample period[a]	*n* Landowners	*n* Fields	*n* Cores	Rice abundance		
					$\bar{x}$	SE	CV (%)
2000	1	25	47	470	339.9	65.9	19.4
	2	27	40	400	302.1	71.1	23.5
	3	27	40	400	153.2	38.8	25.4
	4	27	40	400	115.6	27.3	23.6
2001	1	35	70	700	247.1	56.0	22.7
	2	18	36	360	103.3	29.3	28.3
	3	18	36	360	41.0	8.4	20.6
	4	35	69	690	54.3	12.3	22.7
2002	1	20	40	400	226.1	55.9	24.7
	2	25	50	500	96.8	22.8	23.6
	3	25	50	500	81.2	24.2	29.8
	4	25	50	500	65.4	20.4	31.2
2000–2002	1	80	157	1,570	271.0	34.3	12.7
	2	70	126	1,260	167.4	26.7	16.0
	3	70	126	1,260	91.8	15.5	16.9
	4	87	159	1,590	78.4	12.1	15.4

[a] 1, late September–early October; 2, late October; 3, mid-November; 4, early December.

previous studies in California, we expected rice abundance to differ between harvest methods (HM; combines with stripper vs. conventional headers; Miller and Wylie 1996) and vary among postharvest field treatments (FT; burning, discing, rolling, standing stubble [no treatment], or combinations thereof; Miller et al. 1989). Finally, we expected fields with greater rice abundance postharvest (PHRA) to have increased rice in late autumn, and included this variable in 8 candidate models.

We measured LAT (Universal Transverse Mercator [UTM] northing [m]) as the centroid of each field. We obtained temperature and precipitation data for weather stations nearest to sampled fields from the Department of Geosciences, Mississippi State University (MSU; C. L. Wax, MSU, personal communication). We calculated TEMP as the proportion of days between initial and final field sampling with daily temperatures $\geq$10°C and PRECIP as cumulative precipitation between the median harvest date for each state (National Agriculture Statistics Service 1999–2003) and the last date we sampled a field. We determined HM and FT during sampling.

We did not include a year effect in candidate models because of potential confounding with weather variables, a desire to identify variables related to rice abundance throughout our study, and to maximize available sample size (n = rice fields). Before model selection, we evaluated collinearity among covariates using variance inflation factor diagnostics (PROC REG; SAS Institute 1999). We also deleted data from 3 fields (1.9% $n = 159$) because these observations were outliers (i.e., Studentized residuals >3 and Cook's D values $>4/n$; Freund and Littell 1991:64–70). Additionally, we evaluated the assumption of equal variances by modeling the covariance structure in PROC MIXED (Littell et al. 1996) and determined that models with unequal variances best supported our data (i.e., least Akaike's Information Criterion [AIC]). We then fit candidate models using the appropriate variance structure and the maximum likelihood estimation method (METHOD = ML) in PROC MIXED (Littell et al. 1996). We determined best approximating and competing models by computing AIC adjusted for small sample size (AIC_c; Burnham and Anderson 1998). Additionally, we evaluated model fit using the coefficient of determination (R^2). We considered variables significant if 95% confidence intervals about the parameter estimates did not include zero.

Results

Bias Correction

We recovered 90% ($n = 764$) of seeds placed in test samples. We did not detect variation in recovery ratio among year–treatment combinations ($F_{15,40} = 0.82$, $P = 0.65$). We concluded the best estimate of the ratio between added and recovered seeds in test samples (i.e., bias correction) was the mean over all samples ($\hat{\bar{R}} = 1.105$; SE[$\hat{\bar{R}}$] = 0.017; $n = 56$).

Abundance of Waste Rice

We sampled rice fields of 27–35 landowners annually between 21 September and 7 December 2000–2002 (Table 1). The number of landowners sampled varied among sampling periods within years because not all landowners harvested rice simultaneously. Additionally, we decreased the number of landowners sampled by 50% during periods 2 and 3 in 2001 to allocate increased effort to sampling periods 1 and 4 (i.e., postharvest and late autumn). We sampled 36–70 fields among time periods and years and collected and processed 5,680 core samples.

Large decreases in waste-rice abundance occurred each year between harvest and late autumn (Table 1). In 2000, bias-corrected waste-rice abundance declined 66% from 339.9 kg/ha (SE = 65.9) postharvest to 115.6 kg/ha (27.3) in late autumn. Rice abundance in 2001 was 247.1 kg/ha (56.0) postharvest and 54.3 kg/ha (12.3) in late autumn, representing a 78% decline. In 2002, waste-rice abundance declined 71% from 226.1 kg/ha (55.9) postharvest to 65.4 kg/ha (20.4) by late autumn. Based on regression analyses, there was little evidence of variation among years during the postharvest and late autumn periods (linear

Table 2. Bias-corrected estimates of mean waste-rice abundance (kg/ha, dry mass) by harvest method, and standard errors (SE), coefficients of variation (CV), and 95% confidence limits of estimates for postharvest (PH) and late autumn (LA) sampling periods, Mississippi Alluvial Valley, 2000–2002.

Year	Sample period	Harvest method[a]	$\bar{x}$	SE	CV (%)	Lower 95% CL	Upper 95% CL
2000	PH	C	306.1A[b]	56.5	18.5	195.4	416.9
		S	460.1A	133.2	28.9	199.2	721.1
	LA	C	122.0A	36.4	29.8	50.6	193.3
		S	99.2A	41.5	41.8	17.9	180.6
2001	PH	C	226.4A	74.3	32.8	80.7	372.1
		S	292.1A	29.3	10.0	234.7	349.5
	LA	C	59.0A	18.6	31.6	22.5	95.5
		S	43.8A	7.8	17.9	28.5	59.2
2002	PH	C	144.1A	38.1	26.4	69.5	218.8
		S	312.9B	55.3	17.7	204.5	421.3
	LA	C	72.7A	26.7	36.7	20.5	125.0
		S	59.9A	30.7	51.2	−0.2	120.0
2000–2002	PH	C	225.6A	33.7	15.0	159.5	291.6
		S	355.0A	49.2	13.9	258.5	451.6
	LA	C	84.6A	16.3	19.3	52.6	116.5
		S	67.7A	17.4	25.7	33.5	101.8

[a] C, harvested by a combine equipped with a conventional header; S, harvested by a combine with stripper header.
[b] Mean rice abundance within each year and sampling period combination followed by unlike capital letters differ ($z = -2.51$, $P = 0.012$).

contrast; $-0.51 \leq t_{64} \leq 1.83$; $P > 0.07$), although rice abundance during late autumn was greater in 2000 than 2001 ($t_{64} = 2.42$, $P = 0.019$). Averaged over years, waste-rice abundance decreased 71% from 271.0 kg/ha (34.3) postharvest to 78.4 kg/ha (12.1) in late autumn. Fitting a linear trend over time indicated rice abundance decreased approximately 57.9 kg/ha (SE = 8.8) between biweekly sampling periods. Subtracting the giving-up abundance of rice (i.e., 50 kg/ha) from the late autumn overall estimate indicated the ecological abundance of waste rice was <30 kg/ha.

Most estimates of rice abundance by harvest method (i.e., domain) were imprecise (CVs = 18–51% Table 2). Rice abundance differed between harvest methods in only 1 test within years and sampling periods; rice abundance was greater ($z = -2.51$, $P = 0.012$) for stripper header combines (312.9 kg/ha) than conventional combines (144.1 kg/ha) at postharvest 2002 (Table 2). There was a trend toward greater rice abundance for stripper header combines in all postharvest periods (Table 2), and when we combined probabilities (Sokal and Rohlf 1981:779–782) from tests within years, the overall difference was significant ($\chi^2_6 = 13.13$, $P = 0.04$). In contrast, there was no difference in rice abundance between harvest methods in late autumn ($\chi^2_6 = 2.93$, $P = 0.82$; Table 2).

Modeling Rice Abundance

Of 15 models formulated to predict late autumn rice abundance, the best approximating model contained only additive effects of HM and PHRA. Model HM + PHRA accounted for 98% of the model weight (w_i; Table 3) and explained 17% of the variation in rice abundance among years. Parameter estimates from this model indicated rice abundance in late autumn was 25.8 kg/ha greater (SE = 10.9; 95% CI = 4.5–47.1) in fields harvested with conventional combines and increased 0.10 kg/ha (SE = 0.02; 95% CI = 0.06–0.14) for every 1.0 kg/ha increase in postharvest rice abundance. The next-best model was 8.4 AIC_c units from the best model and not considered competitive (Table 3). The best model that did not include PHRA was 212.8 AIC_c units from model HM + PHRA (Table 3).

Table 3. Candidate models for explaining variation in mean waste-rice abundance among fields in the Mississippi Alluvial Valley in late autumn 2000–2002, ranked by second-order Akaike's Information Criterion (AIC_c). Also included are the number of estimable parameters (K), –2-log likelihood score ($-2\log(\mathscr{L}(\hat{\theta}))$), model weight ($w_i$), and model fit ($R^2$). 33

Model	K	$-2\log(\mathscr{L}(\hat{\theta}))$	AIC_c	ΔAIC_c	w_i	R^2
HM[a] + PHRA[b]	4	1,594.0	1,602.3	0.0	0.980	0.17
FT[c] + HM + PHRA	10	1,589.0	1,610.7	8.4	0.015	0.21
TEMP[d] + PRECIP[e] + LAT[f] + FT + HM + PHRA	13	1,585.2	1,614.0	11.7	0.003	0.22
TEMP + PRECIP + TEMP*PRECIP + LAT + FT + HM + PHRA	14	1,584.6	1,615.9	13.6	0.001	0.23
PHRA	3	1,610.6	1,616.8	14.5	0.001	0.15
LAT + PHRA	4	1,610.2	1,618.5	16.2	0.000	0.15
TEMP + PRECIP + PHRA	5	1,608.8	1,619.2	16.9	0.000	0.16
TEMP + PRECIP + TEMP*PRECIP + PHRA	6	1,607.0	1,619.6	17.3	0.000	0.17
HM	3	1,808.9	1,815.1	212.8	0.000	0.01

[a] Harvest method (HM; stripper or conventional header combine).
[b] Estimated rice seed abundance postharvest (PHRA; e.g., late Sep–early Oct).
[c] Field treatment (FT; discing, burning, rolling, or combination of ≥2 management practices).
[d] Proportion of days from median harvest date to final sampling date with maximum temperatures >10°C (TEMP).
[e] Cumulative precipitation from median harvest date to final sampling date (PRECIP).
[f] Northing Universal Transverse Mercator (UTM) coordinate for field centroid (LAT).

Discussion

Abundance of Waste Rice

Waste grain available to wildlife has remained abundant over time in some agricultural systems because increased production has compensated for increased harvest efficiency (e.g., Warner et al. 1989). Historic data on mean rice yields in Arkansas during 1941–1950 (2,458 kg/ha; Salton 2001) and harvest losses during the late 1940s (6–7% McNeal 1950) suggested waste-rice abundance was 150–175 kg/ha following harvest. In our study, estimates of waste rice following harvest (226.1–339.9 kg/ha; Table 1) and rice yield during 1991–2000 (6,291 kg/ha; Salton 2001) suggest harvest losses were 4–6%. Thus, increased production apparently has offset increased harvest efficiency, and waste rice has remained abundant at harvest time.

Waste rice provides most benefits to waterfowl if exploitation occurs soon after harvest. For example, median dates of rice harvest are approximately 2 weeks later in California's Central Valley (CCV; 10 Oct) than in the MAV (25 Sep; National Agriculture Statistics Service 1999–2003). Further, great numbers of waterfowl arrive in the CCV by October (Heitmeyer et al. 1989), compared with late November in the MAV (Bellrose 1980). Waste rice is likely to remain an important food of CCV waterfowl as long as increases in grain production offset increases in harvest efficiency. Waste rice also may remain abundant at harvest in the MAV, but progressively earlier harvest dates (Anders, in press) may decrease its availability and quality as waterfowl forage. Our overall estimate of waste-rice abundance in late autumn (78.4 kg/ha) is less than observed in the 1980s (140–223 kg/ha; Reinecke et al. 1989) and approaching the threshold level thought to limit efficient feeding and result in habitat abandonment by waterfowl (50 kg/ha; Reinecke et al. 1989, Rutka 2004).

Germination, decomposition, and granivory apparently are primary mechanisms of rice loss after harvest. Rice losses to these agents increase with time and, as competing risks, are difficult to quantify. Because rice seed can germinate when soil temperatures exceed 10°C (Miller and Street 2000), early harvests increase the frequency of conditions favorable for germination. Previous researchers have reported germination of rice following harvest (McGinn and Glasgow 1963, Manley et al. 2004), and we observed rice seedlings in most fields that we sampled. Rice seeds decompose relatively slowly compared with other agricultural seeds when flooded during winter (Neely 1956, Shearer et al. 1969), but increased exposure time following harvest and before flooding undoubtedly exacerbate losses. Stafford (2004) attempted to quantify mechanisms of rice loss in the MAV during autumn by placing known numbers of seeds in plots and protecting half of them from granivores. On average, 20% of seeds remained in late autumn (i.e., potential waterfowl food), 8% germinated, 14% was consumed, and the remaining 58% apparently decomposed (Stafford 2004). Cumulative losses (80%) in the experiment were similar to losses (71%) observed during field surveys.

Effects of Harvest Methods

Research from California caused concern about changes in harvest technology because fields harvested with stripper-header combines had less waste rice and attracted fewer waterbird species than conventionally harvested fields (Miller and Wylie 1996, Day and Colwell 1998). Contrary to those findings, postharvest rice abundance in the MAV was greater in fields harvested by stripper-header than conventional combines in 2002 and overall (355.0 vs. 225.6 kg/ha; Table 2). Because stripper-header combines travel at greater speeds than conventional combines, more rice may be lost to stripper header harvest, or MAV farmers may tolerate increased rice losses for decreased harvest cost.

Although rice abundance was greater during postharvest in fields harvested with stripper headers, results of modeling revealed more rice was available in conventionally harvested fields in late autumn. We do not understand the mechanism for this reversal; however, it may be related to greater amounts of standing stubble and food availability in stripper than conventionally harvested fields. For example, biomass of small mammals may be positively associated with vegetative cover (Monadjem 1997), and species diversity of small mammals may be less in mowed and grazed grasslands (Clark et al. 1998). We speculate that greater amounts of waste rice and standing rice straw in stripper-header than conventionally harvested fields provided improved habitat for small mammals and birds, thereby disproportionately increasing consumption of waste grain in the former fields.

Consequences of Reduced Rice Abundance

An objective of the LMVJV was to establish habitat conditions capable of sustaining 4 million dabbling ducks for a 110-day wintering period in the MAV states we sampled (Loesch et al. 1994). A priority and important management strategy was to encourage landowners to flood harvested rice and other croplands in winter to increase available waterfowl foraging habitat (LMVJV Management Board 1990). Carrying capacity of foraging habitats was measured as duck-use days (DUDs), defined as the number of days an area of habitat can provide food for a mallard (*Anas platyrhynchos*)-sized duck. Based on estimates of waste-rice abundance from the 1980s (Reinecke et al. 1989) and assumptions about energy required by mallards and available from rice and other seeds (Reinecke and Loesch 1996), the LMVJV estimated rice fields provided 1,858 DUDs/ha (Loesch et al. 1994).

We used the equation in Reinecke et al. (1989:236) to provide an updated estimate of DUDs. As in previous work (Reinecke and Loesch 1996), we assumed mallard energy requirements were 292 kcal/day (Prince 1979). Unlike previous work, we used 3.34 kcal/g as the true metabolizable energy of rice (Reinecke et al. 1989) and did not account for seeds other than rice because Manley et al. (2004) reported few (3.98 kg/ha; <3%) moist-soil seeds were available in Mississippi rice fields. When we assumed waterfowl completely consumed rice available in late autumn (78.4 kg/ha; Table 2), the number of DUDs calculated from gross abundance was 897/ha. However, when we assumed waterfowl abandoned fields when abundance was <50 kg/ha (Reinecke et al. 1989, Rutka 2004), the number of DUDs calculated from ecological abundance was 325/ha. Depending on assumptions, our estimates of carrying capacity were only 17% (325 vs. 1,858 DUDs/ha) to 48% (897 vs. 1,858 DUDs/ha) of the value assumed by the LMVJV.

We considered 2 scenarios regarding the extent of rice fields managed for waterfowl in the MAV to illustrate the landscape-scale consequences of decreased rice abundance (e.g., Miller and Newton 1999). Using aerial surveys, Uihlein (2000) estimated

80,830 ha of rice were flooded in the MAV during winters 1992–1993 through 1994–1995. Based on Uihlein's data and the original estimate of carrying capacity (1,858 DUDs/ha), the LMVJV expected rice fields to satisfy 34% (150 million of 440 million DUDs) of the food requirement of dabbling ducks (R. R. Wilson, U.S. Fish and Wildlife, personal communication). Applying our estimates of ecological (325 DUDs/ha) and gross carrying capacity (897 DUDs/ha) to the same habitat data indicated rice fields provided 6% (26.3 million DUDs) and 16% (72.5 million DUDs) of the goal.

The second scenario considered increases in the area of flooded rice fields that may have occurred since Uihlein's (2000) study as a result of programs encouraging habitat management by private landowners (Baxter et al. 1996). Analysis of satellite images by Ducks Unlimited, Inc. indicated 126,515 ha of rice fields were flooded in the MAV on 3–4 January 2003 (T. E. Moorman, Ducks Unlimited, Inc., unpublished data). Applying our estimates of gross and ecological carrying capacity to these data indicated rice fields provided 9 and 26% of the food requirement of dabbling ducks. Although the LMVJV expected flooded rice fields to provide 34% of the food required by wintering dabbling ducks, we concluded rice fields currently provided 6–9%, and at most 16–26%, of that goal.

Reduced food availability may negatively influence body condition of waterfowl. Krapu et al. (2004) attributed declines in mean body fat of greater sandhill cranes (*Grus canadensis tabida*) and fat deposition rates in white-fronted geese (*Anser albifrons*) to decreasing corn abundance (caused by increased harvest efficiency) in central Nebraska for the period 1978–1998. Our study demonstrated waste-rice abundance in late autumn has decreased in the MAV despite increases in rice yield and area of rice fields flooded for waterfowl (National Agriculture Statistics Service 1999–2003, Manley et al. 2004). However, consequences of reduced rice abundance to body condition and fitness of waterfowl are unknown, and we recommend research using radio-marked birds to assess foraging habitat use in relation to energetic costs, body condition at capture or recapture, and survival.

Management Implications

Future research should examine factors potentially influencing and exacerbating rice-seed loss. For example, we recommend research to investigate potential competition for waste rice between overabundant snow geese (*Chen caerulescens*), other waterfowl, and wildlife in the MAV. Also, researchers should evaluate management practices (i.e., burning, rolling, discing, no manipulation) that conserve waste rice; this effort could benefit waterfowl and landowners who lease ricelands for hunting (Grado et al. 2001). Additionally, we recommend interdisciplinary research with agricultural scientists to determine the potential of early maturing rice varieties to produce a second or ratoon crop. Finally, we recommend the LMVJV monitor annual rice harvest dates in the MAV. If harvest dates become increasingly earlier due to evolving rice varieties and other management practices, the LMVJV should re-estimate waste-rice abundance to determine if food abundance in harvested fields has decreased further.

Waterfowl foraging carrying capacity of harvested rice fields was markedly less in our study than assumed by the LMVJV. Therefore, we recommend conservation planners adopt a value of 325 DUDs/ha (i.e., ecological abundance of rice = 28.4 kg/ha) as the best current estimate of carrying capacity. To mitigate reduced forage in ricelands, we recommend increased management of alternative foraging habitats, especially moist-soil plant communities (Reinecke et al. 1989). Penny (2003:78) sampled moist-soil seed abundance in fall 2002 in management units on public lands throughout the MAV and reported the carrying capacity of these areas averaged 5,168 DUDs/ha. Research is continuing throughout the MAV to evaluate this preliminary estimate of carrying capacity and the giving-up abundance of seeds in moist-soil habitats (R. M. Kaminski, MSU, personal communication).

Acknowledgments

Principal and initial funding for our research was provided by Ducks Unlimited, Inc., through the Institute for Wetland and Waterfowl Research, and the North American Wetlands Conservation Council. Support was also provided by Federal Aid in Wildlife Restoration through the Mississippi Department of Wildlife, Fisheries and Parks (Project W-48, Study 44), the Arkansas Game and Fish Commission, MSU Forest and Wildlife Research Center (FWRC) and Delta Research and Extension Center, and the U.S. Geological Survey, Patuxent Wildlife Research Center. We are indebted to the rice farmers in the MAV who allowed us to sample their fields. We could not have completed this project without help from many individuals, including B. Batt, M. Checkett, B. Dugger, P. Gerard, D. Godwin, K. Hartke, D. Jackson, B. Leopold, M. Kurtz, M. Petrie, T. Moorman, D. Rutka, B. Uihlein, and R. Wilson. Finally, we thank the following people who assisted with field, lab, and/or analytical work, especially J. Arnold, B. Bowers, C. Galle, B. Holder, N. Jerstad, J. Kross, A. Pearse, E. Penny, E. Seckinger, M. Stafford, J. Vest, T. Whyte, and C. Woods. The senior author also thanks the Illinois Natural History Survey for their support. Our manuscript was approved for publication as MSU-FWRC Journal Article WF-204.

Literature Cited

Anders, M. M. In press. Agronomic implications of conservation practices in ricelands. S. W. Manley, editor. Conservation in ricelands of North America. Ducks Unlimited, Memphis, Tennessee, USA.

Anderson, D. R., K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912–923.

Baxter, C. K., J. Leach, and C. Lively. 1996. The role of private lands in implementing the North American Waterfowl Management Plan. Pages 241–249. *in* J. T. Ratti, editor. Proceedings of the Symposium on Waterfowl Management, Memphis, Tennessee, USA.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Stackpole, Harrisburg, Pennsylvania, USA.

Bird, J. A., G. S. Pettygrove, and J. M. Eadie. 2000. The impact of waterfowl foraging on the decomposition of rice: mutual benefits for rice growers and waterfowl. Journal of Applied Ecology 37:728–741.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock.

1987. Design and analysis of fish survival experiments based on release–recapture data. American Fisheries Society, Bethesda, Maryland, USA.
Canadian Wildlife Service and U.S. Fish and Wildlife Service. 1986. North American waterfowl management plan. Canadian Wildlife Service, Ottawa, Ontario, Canada, and U.S. Fish and Wildlife Service, Washington, D.C., USA.
Clark, B. K., B. S. Clark, T. R. Homerding, and W. E. Munsterman. 1998. Communities of small mammals in six grass-dominated habitats of southeastern Oklahoma. American Midland Naturalist 139:262–268.
Cochran, W. G. 1977. Sampling techniques. John Wiley and Sons, New York, New York, USA.
Conroy, M. J., J. R. Goldsberry, J. R. Hines, and D. B. Stotts. 1988. Evaluation of aerial transect surveys for wintering American black ducks. Journal of Wildlife Management 52:694–703.
Day, J. H., and M. A. Colwell. 1998. Waterbird communities in rice fields subjected to different post-harvest treatments. Colonial Waterbirds 21:185–197.
Delnicki, D., and K. J. Reinecke. 1986. Midwinter food use and body weights of mallards and wood ducks in Mississippi. Journal of Wildlife Management 50:43–51.
Forsythe, S. W. 1985. The protection of bottomland hardwood wetlands of the lower Mississippi Valley. Transactions of the North American Wildlife and Natural Resources Conference 50:566–572.
Forsythe, S. W., and S. W. Gard. 1980. Status of bottomland hardwoods along the lower Mississippi River. Transactions of the North American Wildlife and Natural Resources Conference 45:33–340.
Franklin, A. B., D. R. Anderson, and K. P. Burnham. 2002. Estimation of long-term trends and variation in avian survival probabilities using random effects models. Journal of Applied Statistics 29:267–287.
Freund, R. J., and R. C. Littell. 1991. SAS System for regression. SAS Institute, Cary, North Carolina, USA.
Galloway, G. E., Jr. 1980. Ex-post evaluation of regional water resources development: the cases of the Yazoo-Mississippi Delta. U.S. Corps of Army Engineers, Institute for Water Resources. Report IWR-80-D1, Alexandria, Virginia, USA.
Grado, S. C., R. M. Kaminski, I. A. Munn, and T. A. Tullos. 2001. Economic impacts of waterfowl hunting on public lands and at private lodges in the Mississippi Delta. Wildlife Society Bulletin 29:846–855.
Heitmeyer, M. E., D. P. Connelly, and R. L. Pederson. 1989. The Central, Imperial, and Coachella valleys of California. Pages 475–505 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.
Huitink, G., and T. Siebenmorgen. 1996. Maintaining yield and grain quality. 79–85 R. S. Helms, editor. Rice production handbook. Cooperative Extension Service, University of Arkansas, Publication number MP–192. Fayetteville, Arkansas, USA.
Joyner, D.E., B.N. Jacobson, and R.D. McArthur. 1987. Nutritional characteristics of grains fed to Canada geese. Wildfowl 38:89–93.
Krapu, G. L., D. A. Brandt, and R. R. Cox. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management. Wildlife Society Bulletin 32: 127–136.
Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. SAS Institute, Cary, North Carolina, USA.
Loesch, C. R., and R. M. Kaminski. 1989. Winter body-weight patterns of female mallards fed agricultural seeds. Journal of Wildlife Management 53: 1081–1087.
Loesch, C. R., K. J. Reinecke, and C. K. Baxter. 1994. Lower Mississippi Valley Joint Venture Evaluation Plan. North American Waterfowl Management Plan, Vicksburg, Mississippi, USA.
Lohr, S. L. 1999. Sampling: design and analysis. Duxbury, Pacific Grove, California, USA.
Lower Mississippi Valley Joint Venture Management Board. 1990. Conserving waterfowl and wetlands: the Lower Mississippi Valley Joint Venture. North American Waterfowl Management Plan, Vicksburg, Mississippi, USA.
Manley, S. W., R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. 2004. Waterbird-foods in winter-managed rice fields in Mississippi. Journal of Wildlife Management 68:74–83.
Manley, S. W., R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. In Press. Agronomic implications of waterfowl management in Mississippi ricefields. Wildlife Society Bulletin.
McGinn, L. R., and L. L. Glasgow. 1963. Loss of waterfowl foods in ricefields in southwest Louisiana. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 17:69–79.
McNeal, X. 1950. Effect of combine adjustment on harvest losses in rice. University of Arkansas, Fayetteville, USA.
Miller, M. R., and W. E. Newton. 1999. Population energetics of northern pintails wintering in the Sacramento Valley, California. Journal of Wildlife Management 63:1222–1238.
Miller, M. R., and G. D. Wylie. 1996. Preliminary estimate of rice present in strip-harvested fields in the Sacramento Valley, California. California Fish and Game 82:187–191.
Miller, M. R., D. E. Sharp, D. S. Gilmer, and W. R. Mulvaney. 1989. Rice available to waterfowl in harvested fields in the Sacramento Valley, California. California Fish and Game 75:113–123.
Miller, T. C., and J. E. Street. 2000. Mississippi's rice growers guide. Mississippi State University Extension Service publication 2255, Mississippi State, USA.
Milliken, G. A., and D. E. Johnson. 1992. Analysis of messy data, volume I: designed experiments. Chapman & Hall, New York, New York, USA.
Monadjem, A. 1997. Habitat preferences and biomasses of small mammals in Swaziland. African Journal of Ecology 35:64–72.
Mood, A. M., F. A. Graybill, and D. C. Boes. 1974. Introduction to the theory of statistics. McGraw-Hill, New York, New York, USA.
National Agricultural Statistics Service. 1999–2003. Crop production summaries, 1999–2003. U.S. Department of the Agriculture, National Agricultural Statistics Service, Agricultural Statistics Board, Washington, D.C., USA.
Neely, W. W. 1956. How long do duck foods last underwater? Transactions of the North American Wildlife and Natural Resources Conference 21:191–198.
Nelms, C. O., and D. J. Twedt. 1996. Seed deterioration in flooded agriculture fields during winter. Wildlife Society Bulletin 24:85–88.
Penny, E. J. 2003. Estimating moist-soil plant seed availability in the Mississippi Alluvial Valley. Thesis, Mississippi State University, Mississippi State, USA.
Prince, H. H. 1979. Bioenergetics of postbreeding dabbling ducks. Pages 103–117 in T.A. Bookhout, editor. Waterfowl and wetlands: an integrated review. Proceedings of the 1977 Symposium of the North Central Section of the Wildlife Society, Madison, Wisconsin, USA.
Reinecke, K. J., and C. R. Loesch. 1996. Integrating research and management to conserve wildfowl (Anatidae) and wetlands in the Mississippi Alluvial Valley, USA. Gibier Faune Sauvage, Game Wildfowl 13:927–940.
Reinecke, K. J., R. C. Barkley, and C. K. Baxter. 1988. Potential effects of changing water conditions on mallards wintering in the Mississippi Alluvial Valley. Pages 325–337 *in* M. W. Weller, editor. Waterfowl in winter. University of Minnesota Press, Minneapolis, USA.
Reinecke, K. J., R. M. Kaminski, K. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pages 203–247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, USA.
Rutka, D. M. 2004. Waste rice depletion by waterfowl wintering in the Mississippi Alluvial Valley. Thesis, Southern Illinois University, Carbondale, USA.
Salton, N. A. 2001. Arkansas rice production handbook. University of Arkansas Cooperative Extension Service publication MP192-10M, Fayetteville, USA.
SAS Institute. 1999. SAS/STAT User's Guide. SAS Institute, Cary, North Carolina, USA.
Sauer, J. R., and B. K. Williams. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. Journal of Wildlife Management 53:137–142.
Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Macmillan, New York, New York, USA.
Shearer, L. A., B. J. Jahn, and L. Lenz. 1969. Deterioration of duck foods when flooded. Journal of Wildlife Management 33:1012–1015.
Sokal, R. R., and F. J. Rohlf. 1981. Biometrics: the principles and practice of statistics in biological research. Freeman, San Francisco, California, USA.
Stafford, J. D. 2004. Abundance and conservation of waste rice for wintering waterfowl in the Mississippi Alluvial Valley. Dissertation, Mississippi State University, Mississippi State, USA.
Stafford, J. D., K. J. Reinecke, and R. M. Kaminski. 2003. SAS procedures for designing and analyzing sample surveys. Bulletin of the Ecological Society of America 84:111–114.

Stephens, D. W., and J. R. Krebs. 1986. Foraging theory. Princeton University Press, Princeton, New Jersey, USA.
Uihlein, W. B. 2000. Extent and distribution of waterfowl habitat managed on private lands in the Mississippi Alluvial Valley. Dissertation, Mississippi State University, Mississippi State, USA.
Warner, R. E., S. P. Havera, L. M. David, and R. J. Siemers. 1989. Seasonal abundance of waste corn and soybeans in Illinois. Journal of Wildlife Management 53:142–148.
Yoshida, S. 1981. Fundamentals of rice crop science. International Rice Research Institute, Los Baños, Philippines.

Associate Editor: Ransom.